Bank of Israel **Research Department**

Why the Bank of Israel Intervenes in the Foreign Exchange Market, and What Happens to the Exchange Rate

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Discussion Paper No. 2017.04

February 2017

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The views expressed are solely those of the author and do not necessarily reflect the views of the Bank of Israel, or any of its staff.

** I thank Joseph Djivre and the participants of the Bank of Israel Research Department and participants in the RCEA Money-Macro-Finance Workshop in Rimini for their helpful comments and suggestions.

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מדוע מתערב בנק ישראל בשוק המט״ח ומה קורה לשער החליפין?

סיגל ריבון

תקציר

ב-2008 חידש בנק ישראל את התערבותו בשוק המט״ח, לאחר עשור ללא התערבות. המחקר בוחן באיזו מידה השפיעה התערבות זו על שער החליפין האפקטיבי של השקל. אנו משתמשים באמידה דו-שלבית המאפשרת לבחון גם את הגורמים המשפיעים על עיתוי ההתערבות ועל היקפה. התוצאות מעלות כי ההתערבות תרמה לפיחות בשער החליפין: היקפה הממוצע – כ-830 מיליון דולר בחודש בתקופה שנבחנה – יצר בחודש כזה פיחות גדול בכ-0.6 נקודות אחוז מהפיחות בחודש ללא התערבות. עוד נמצא כי את היקף ההתערבות מסבירה (בדיעבד) רמת היתרות ביחס לתוצר וסטייתו של שער החליפין הריאלי משיווי המשקל של הטווח הארוך. נמצאה גם תמיכה לגישת ההליכה נגד הרוח ("leaning against the wind") בהתנהגותו של הבנק המרכזי. התוצאות תומכות בתפיסה שלערוץ האיתות יש חשיבות בהסבר ההשפעה של ההתערבות על שער החליפין.

Why the Bank of Israel Intervenes in the Foreign Exchange Market,

and What Happens to the Exchange Rate

Sigal Ribon

Abstract

The Bank of Israel renewed its intervention in the foreign exchange market in early 2008 after about a decade of not intervening. This study examines the effect of the Bank's purchases on the shekel exchange rate. The two-stage estimation approach provides the opportunity to understand the factors influencing the timing and scope of the intervention. The results of the estimation show that the Bank of Israel's purchases contributed to a depreciation of the shekel. The average monthly volume of purchases for periods in which the Bank of Israel actually intervened in the market, approximately $830 million, contributed to a depreciation in the nominal effective exchange rate that was larger by about 0.6 percent, compared with a month with no intervention. The level of foreign exchange reserves (relative to GDP) and the deviation of the real exchange rate from its long-term equilibrium level tend to increase the volume of purchases by the central bank. Support for "leaning against the wind" behavior by the central bank was also found. The results suggest that the "signaling channel" is important in explaining the effect of intervention on the exchange rate.

1. Introduction and a Short Review of the Literature

Since March 2008, the Bank of Israel has been intervening in the foreign exchange market. Following intervention on a large scale in March 2008, given the exceptional appreciation and volatility of the exchange rate at that time, the Bank of Israel (BoI) began intervening on a predetermined scale—first $25 million daily, and for a year beginning in July 2008, $100 million daily. Since mid-August 2009, the Bank of Israel's intervention in the market has been in variable amounts at its discretion.[1]

The purpose of this study is to examine whether the Bank of Israel's intervention in the foreign exchange market has had an effect on the nominal exchange rate. In order to do this, and as a byproduct of the examination of the exchange rate, we propose a description of the factors affecting the volume of purchases by the central bank.

Intervention in the foreign exchange market is a tool of monetary policy, in addition to the primary tool—the interest rate set by the central bank. It is conducted while maintaining the declared interest rate. In other words, the BoI's intervention is sterilized—it adjusts the supply of domestic currency liquidity so that the declared interest rate is maintained.[2] The analysis described here tests the effect of the intervention on the exchange rate, given the interest rate.

The main difficulty in estimating the effect of the intervention on the exchange rate is its endogeneity—the decision to intervene (in this case, purchase foreign currency) depends on the evolution of the exchange rate. Estimation without addressing this problem may therefore yield results contrary to those expected. One of the customary solutions to the endogeneity problem is to use daily or intraday data for intervention, assuming that the change in the exchange rate during the short time examined is solely a response to the intervention carried out at precisely the same time, and that the decision to intervene was taken (slightly) earlier.[3] The disadvantage of that approach is that it makes it possible to test only a very short-term

[1] In addition, starting in mid-2013, the Bank of Israel has intervened in the market as part of a program of purchases in order to offset the effect of natural gas production in Israel on the exchange rate. See press release by the Bank of Israel dated May 13, 2013.
http://www.boi.org.il/en/NewsAndPublications/PressReleases/Pages/13052013m.aspx

[2] Throughout the period the level of the interest rate was always positive. Starting from March 2015 until the end of the sample, it was 0.1 percent (See Figure 9).

[3] The use of daily data can also be advantageous in the framework of estimation at lower frequencies. See Gertler and Karadi (2015) and others, who propose using daily data from the capital market to identify monetary shocks in the framework of a VAR model with monthly frequency.

effect of the intervention on the exchange rate. Another method, which enables the use of lower frequency data and that is employed here, is to proxy the intervention with instruments that are correlated with it, but not with the shocks to the exchange rate. The disadvantages of this method are the difficulty in finding instrumental variables with the desired characteristics and the possible dependence of the results on their selection. The advantage of this approach is that it allows the analysis of the factors affecting the central bank's decision to intervene and the reaction of the market at frequencies that are more meaningful from a macroeconomic perspective. Neely (2005) reviews the empirical research in this area, and cites two common types of analysis: event studies and the use of daily data. In his review, he cites only two articles that use monthly data.

The two key conventional channels through which intervention in the foreign exchange market is assumed to affect the exchange rate are the *portfolio channel* and the *signaling channel*.[4] According to the *portfolio approach*, by conducting sterilized forex purchases, the central bank increases the supply of assets in domestic currency. The result is excess supply of domestic assets. Under the assumption that the assets are imperfect substitutes and that individuals are risk averse, the exchange rate (and the interest rates) should respond in order to return to equilibrium. If we assume that the (short term) interest rate is fixed, then the exchange rate must react to restore equilibrium. Many studies in the 1980s and 1990s dealt with the effect of intervention on the exchange rate, mainly in the US and other advanced economies. Edison (1993) reviews the papers relating to the portfolio channel approach, and concludes that in most cases, there is no evidence that intervention had any effect on the exchange rate through this channel. It is reasonable to assume that in order to affect the price of foreign currency via this channel very large quantities must be brought to the market. Therefore, the possible effect depends on the ability to do so.

The second approach is the *signaling channel*—intervention in the foreign exchange market signals to the public the central bank's intention to take action to prevent the strengthening of the domestic currency (at least to some extent), and possibly also to maintain an accommodative monetary policy. It therefore generates both expectations of a devaluation as well as an actual devaluation. One possible problem with this approach is that the public is sometimes unaware of the interventions and their scope. The same paper (Edison 1993) notes that several articles found that intervention had some significant effect on the exchange rate

[4] See also a theoretical and empirical discussion in Sarno and Taylor (2001).

through the signaling channel. Kaminsky and Lewis (1996) discuss the extent to which intervention by the central bank signals future monetary policy—that is, how much additional information for market participants about future policy is incorporated in the intervention. They find that the exchange rate tends to move significantly in the direction implied by intervention only when interventions are followed by monetary policy that is consistent with the direction of intervention. When intervention is followed by movements in monetary policy in the opposite direction, the exchange rate also tends to move in the opposite direction.

Among the studies published in recent years, an article by Villamizar-Villegas and Perez-Renya (2015) from Colombia's central bank presents an up-to-date survey of empirical studies in the field, and notes that only a few theoretical studies dealing with the question have been published. Most of the studies mentioned in the review relate to the US and Germany, and use various statistical methods, mostly analysis of daily data, therefore examining whether the intervention has an immediate effect on the exchange rate. Only a few studies use intraday data or data with lower than daily frequency. The authors summarize the results of the articles by saying that the effect is small and short-term. Menkhoff (2013) reviews the studies examining the effect of intervention in developing countries, where intervention is more frequent, and where the institutional structure is different than in advanced economies. He reports that the studies usually find an effect on the exchange rate, and the results for an effect on volatility are mixed. A large majority of the articles they survey also use daily data or intraday data; only a few use data with lower frequency. Adler, Lisack, and Mano (2015) are among the few recent articles that use data with lower than daily frequency. Using instrumental variables for monthly data for a panel of countries, they find strong evidence that intervention has a statistically and economically significant effect on the exchange rate—purchasing volumes amounting to one percent of GDP increase the nominal and real exchange rate by 1.4–2 percent. Adler and Tovar (2011) also use panel data. Their sample contains weekly data for 15 countries (including Israel) in 2004–10, but excludes the crisis years (2008–09). By using two-stage least squares (2SLS) estimation for the panel, they find that sterilized intervention slows the pace of appreciation, but that the effect is smaller when the economy is more open to capital flows—intervention of 0.1 percent of GDP in a given week slows appreciation by 0.3 percent. They also find that the intervention is more effective when the appreciation in the exchange rate is “excessive.” In order to help solve the endogeneity problem, they examine only periods of time around major global shocks that are exogenous to

the examined countries. Daude, Levy Yeyati, and Nagengast (2014) estimate the effect of the intervention on the real exchange rate for a panel of 18 developing economies in 2003–11 using monthly data. They find that intervention is effective, and has a greater effect the more the exchange rate deviated from equilibrium. Blanchard, Adler, and de Carvalho Filho (2015) examine whether intervention can weaken the effect of capital inflows on the exchange rate in the examined countries. They instrument endogenous capital inflow using global capital flows, which they assume are exogenous to the small economies being examined, in the framework of a VAR system. According to the capital flows model presented in the paper, the intervention is expected to be accompanied by larger capital inflows (because the risk is smaller), but with a smaller effect on the exchange rate. Despite the difference in exchange rate regimes between countries, according to the estimated VAR system, the currency appreciates in all of them in response to capital inflows. For the group of countries that intervene[5], it was found that exchange rate appreciation in response to capital inflows was less than in the other countries. A relatively new article by Duran-Venegas (2015) examines the effect of the intervention in Colombia using daily data and finds that only when the actual rate is sufficiently distant from this rate is the intervention effective.

In an empirical paper, Fratzscher et al. (2015) examine the effectiveness of intervention, using a unique database containing daily data from 33 countries (including Israel) in 1995–2011. In general, they conclude that the intervention succeeded in smoothing the exchange rate under all types of exchange rate regimes. They find that in floating exchange rate regimes, intervention was less successful in terms of movement of the exchange rate—approximately 60 percent of the cases—and was more successful when the intervention was larger and in accordance with the long-term (three years, on average) trend and direction of the exchange rate, and when it was accompanied by central bank communication with the public.

Summarizing a 2013 conference at the Bank for International Settlements (BIS) dedicated to the subject of the foreign exchange market and intervention, Mohanty (2013) writes that the central bank representatives who attended the conference did not fully agree on how effective intervention is. The consensus was that intervention could reduce volatility, but it was unclear to what extent it could offset a change in the equilibrium exchange rate. Participants were of

[5] The study classifies Israel as a floater, rather than an intervener, because its degree of intervention is less than that of the median country.

the view that intervention could work as a signal, and that it was more effective when accompanied by supplementary measures such as restrictions on capital movements. According to a BIS survey ahead of the conference, approximately 80 percent of the central bankers thought that intervention was partially or completely successful, and some asserted that it had a long-term effect. A paper prepared for the conference by Flug and Shpitzer (2013) describing Israel's experience with intervention in the foreign exchange market discusses in general the need to intervene—first, due to the desire to increase foreign exchange reserves and contribute to market functioning, and later, to moderate the appreciation, thereby supporting exports. The discussion of the empirical test by the Bank of Israel[6] describes a 6.7 percent effect on the exchange rate for one year from the beginning of the intervention, and deduces, based on other studies, a 0.7 percent contribution to growth at the time. It is also stated that the mechanism for transmitting monetary policy through the exchange rate is weakened when the intervention is conducted during a period of rising interest rates (as was the case from late 2009 until late 2012)—in other words, working in the opposite direction. Another BIS article by Chutasripanich and Yetman (2015) cites the gap between the high value placed by central bankers on the effectiveness of intervention and the research findings, which do not yield unequivocal results. In the model presented in their article—with market participants operating in the current account and speculators operating in the capital account and responding to interest rate differentials and the central bank, they find that intervention reduces exchange rate volatility but also reduces the risk to speculators and increases the volume of their activity.

A related strand of literature examines the determinants of foreign exchange intervention by central banks. The main two motives for intervention usually empirically tested are the deviation of the (nominal) exchange rate from a moving average trend and the volatility of the exchange rate. Baillie and Osterberg (1997) find, using a probit model for the probability of intervention, evidence for these two motives for the US and Germany. Kim and Sheen (2002) find in addition that the interest rate differentials, profitability of intervention for the central bank and foreign currency reserve inventories also motivate intervention. More recent examinations of the reasons for intervention, using probit, ordered probit, or friction models for daily data are Horvath (2006) for the Czech Republic who finds that the inflation target regime is a constraint on intervention; Ito and Yabu (2007) for Japanese data who find support

[6] This refers to the study by Sorezcky (2013).

for a "leaning against the wind" policy, and Ozlu and Prokhorov (2008) who find that a linear model or a threshold model describes the Turkish intervention, depending on the regime of the exchange rate market—floating or managed float.

Even though the Bank of Israel has been intervening in the foreign exchange market for several years, only one study analyzing the intervention has been published in Israel[7] examining the effect of the foreign exchange market intervention on the exchange rate. Sorezcky (2013) tested whether the intervention is reflected in an exchange rate that deviates from the one expected based on a VAR system using an equation for the exchange rate excluding the variable describing the intervention. He found that most of the effect was obtained at times when there was a change in the character of the Bank's intervention—the transition from fixed purchases of $25 million per day to $100 million per day, and the transition to variable purchases. He found that the difference between the forecast rate (without intervention) and the actual rate decreased during the first half of 2009, but grew larger again with the announcement of a transition to intervention in variable quantities.[8]

This study focuses on the Israeli economy starting in September 2009, when the Bank of Israel moved to purchasing variable amounts of foreign currency by discretion, with no commitment in advance to a fixed amount, in contrast to the case from March 2008 until that time. Despite the very short period available to us, focusing on a period featuring a single clear exchange rate regime facilitates a more careful examination of the effects of the intervention and allows the drawing of conclusions about the effectiveness of the intervention in this regime. Examining the effect of the intervention on the exchange rate is based on the identification of the factors affecting the supply of, and demand for, foreign currency when one of the factors is demand from the central bank—i.e., its intervention in the foreign exchange market.

The analysis herein is conducted with monthly frequency data, for several reasons. The first is that essentially, from a macroeconomic perspective, monthly frequency is more relevant when considering whether the exchange rate responds to intervention. Second, the

[7] There are studies examining the subject in the framework of a panel of countries in which Israel is included.

[8] Gamarsani, Nathan and Stein (2009) find in an unpublished memo that for data until mid-2009, when intervention was on a pre-announced daily volume, that interventions caused the exchange rate to depreciate on the day of intervention and it is mostly related to news regarding the intervention. Using intra-day data, they find that BOI's interventions announcements have a weak and temporary effect on market expectations.

monthly data are published, easily accessible, and known to the public, and therefore it can be assumed that the public is able to respond, for example with its expectations, to quantities known to them.

Estimation in a panel data framework, as was done in many studies on this topic, has an advantage—the cross section variance provides the ability to characterize links between the economic variables from a broad perspective. Yet at the same time, such estimation usually makes it difficult to fully address the specific conditions in each economy, and the changes that took place in that economy's structural features. This is particularly prominent in specifying the exchange rate regime on the basis of a partial period and the difficulty in taking into account changes that have occurred in the exchange rate regime.[9]

The main findings of this study are that the intervention conducted since mid-2009 contributed to the depreciation of the nominal effective shekel exchange rate, at least in the same month. The estimated effect of intervention is positive and significant for various specifications of the instruments. We find that an increase of $100 million in the monthly intervention is expected to increase the rate of depreciation of the nominal effective exchange rate by 0.07–0.09 percentage points in that month. The monthly volume of purchases in the period when the Bank of Israel actually intervened in the market averaged approximately $830 million (about one third of one percent of annual GDP). According to the estimation results, such intervention makes the depreciation in the nominal effective exchange rate 0.6 percent larger, compared with a month with no intervention. Estimating the effect on the exchange rate using a variable describing the probability of intervention in the market each month yields a higher effect, with effective exchange rate depreciation larger by about 1.1–1.4 percent on average, compared with a month with no intervention. These results are consistent with the hypothesis that intervention has an effect through the signaling channel, not only through its effect on the portfolio. In addition, results of the estimation by subperiods support the hypothesis that the effect of the intervention is larger when it is implemented against the backdrop of an accommodative interest rate policy, compared with a situation in which the interest rate policy is working in the opposite direction. According to the estimation, this

[9] For example, see the classification of Israel in Fratzscher et al. (2015) as an economy with an exchange rate within a band—an identification which is no longer valid—probably on the basis of an examination of the exchange rate policy at the beginning of the period they examine.

effect is of the same magnitude as a reduction of the interest rate by the central bank of 0.25 percentage points.

The estimated volume of intervention generally succeeds in following the actual volume of intervention, including the months in which there was no intervention—from August 2011 to March 2013. The ratio of foreign reserves to GDP contributes to explaining the intervention. The significant effect of the deviation from the long-run equilibrium real exchange rate indicates that this consideration also guides the central bank. A negative effect of an increase in exports on the scope of intervention indicates that support for the exporting sector is also among the considerations for intervention. A negative coefficient for the (lagged) exchange rate and a positive contribution of the standard deviation of the exchange rate (in some of the specifications) are consistent with considerations of reducing volatility according to the "leaning against the wind" approach. The tests conducted also show that the total amount of purchases is better explained than the purchases excluding the natural gas plan.[10] This result indicates that although the annual volume of purchases according to the gas plan is announced in advance, the actual volume of monthly purchases is apparently affected by the market conditions.

The paper has five sections. Section 2 presents the estimation framework. Section 3 presents the estimation results, Section 4 discusses estimation for sub-samples, and Section 5 concludes.

2. The Estimation Framework

The primary goal of this study is to identify the extent of the effect of foreign currency purchases by the Bank of Israel on the nominal exchange rate.

The framework for the analysis is relatively straightforward, based on a description of the foreign exchange market as a perfect market at immediate (short-term) equilibrium. In other words, the shekel exchange rate against other currencies is determined by supply and demand.

In a simplistic description, the supply and demand for foreign currency are associated with changes in the balance of payments. Exports of goods and services and capital imports generate a supply of foreign currency, while imports of goods and services and capital exports

[10] See footnote 1.

generate demand for foreign currency. These flows depend on factors such as economic activity, interest rate differentials, and the perceived risk of the economy. The estimated equation describes in a reduced form the factors determining the nominal exchange rate at equilibrium in the short term.

The identity of the balance of payments expresses the equivalence between the surplus in the current account and the capital account[11] and the economy's overseas investment surplus.[12] We can write:

(1) $CA = FDI\_net + Short\_net + BoI\_pr,$

where CA is the surplus in the current account and the capital account, FDI_net is direct net overseas investment, Short_net is net short-term capital exports, and BoI_pr is foreign currency purchases by the Bank of Israel. A reduced form of the equation for the exchange rate (e) in equilibrium may be derived from (1):

$$\underset{(-)\quad(+)\quad(+)\quad(+)}{(2)\qquad e = f(CA, FDI\_net, Short\_net, BoI\_pr),}$$

and in terms of rate of change:

(2)' $\Delta e = f(\Delta(CA), \Delta FDI\_net, \Delta Short\_net, \Delta BoI\_pr)$

Since the quantities and prices are determined simultaneously, and in order to avoid endogeneity, we estimate the change in the exchange rate (in the second stage) using the estimated value of the intervention from the first stage, as one of the explanatory variables.[13] Finding adequate instrumental variables that are correlated with the intervention but are uncorrelated with the residuals of the exchange rate equation is not an easy task. Statistical tests help us determine whether the identifying variables are sufficient in preventing (too large a) bias in the estimator.

[11] The current account includes trade in goods and services, primary income and secondary income. The capital account includes net remuneration for labor of Israelis overseas, income (interest, etc.) from overseas investment, current transfers and transfers on the capital account.
[12] Summarized in the financial account of the balance of payments.
[13] The approach taken here is very similar to the one presented in Adler and Tovar (2011), where it is used for weekly data in a panel of countries. It differs from the methodology in Daude, Levy Yeyati, and Nagengast (2014), where the dependent variable is the short term deviations of the real exchange rate from its long-term (estimated) level, and the intervention is substituted with the ratio of M2/GDP as an instrumental variable.

2.1 The Bank of Israel's Intervention

The estimated intervention by the Bank of Israel is one of the factors describing the change in the effective exchange rate. Nonetheless, the results of the intervention estimation are important in their own right in contributing to the understanding (retrospectively) of the factors affecting the Bank of Israel's behavior since it switched to a regime in which the quantity and timing of the intervention are variable and not predetermined.

As in other research, estimating the factors affecting the intervention does not rely on a complete theoretical model, albeit it retrospectively describes the factors expected to affect the extent of the intervention according to the conventional approaches (see also Sarno and Taylor, 2001).

The literature mentions two major motives for a central bank's intervention in the foreign exchange market: smoothing excessive fluctuation in the exchange rate (leaning against the wind) and minimizing deviations from the nominal exchange rate trend. Minimizing deviations from the long-term equilibrium real exchange rate and the need to increase the foreign currency reserves in order to reduce the risk to the economy are also mentioned as motives for intervention.

According to the Bank of Israel's announcements to the public, the purpose of its intervention was initially to increase the Bank of Israel's foreign currency reserves up to a quantitative target set and declared in advance[14] and which is "…appropriate to the needs of the rapidly growing Israeli economy and its increasing integration into the global economy and global financial system".

Later, after the outbreak of the global crisis in late 2008, the Bank of Israel slightly altered the way it explained its purchases of foreign currency, together with increasing the weight given to the need to further increase the balances "against the background of the world economic situation and in the context of its overall policy …" and it was stated that the purchases (together with purchases of bonds that took place during the same period) contribute to "strengthening the ability of the economy to cope with the impact of the global

[14] In the Bank of Israel's press release dated March 20, 2008, a target of $35–40 billion is declared.
(http://www.boi.org.il/en/NewsAndPublications/PressReleases/Pages/080321f.aspx).
The target was revised to $40–44 billion in the Bank of Israel's press release dated November 30, 2008. In 2010 the target was raises to $65–90 billion, and in 2015 to $70–110 billion.

economic crisis, which impacts mainly the demand for exports and the resulting slowdown in economic activity. Furthermore these programs support the resilience of the financial system and price stability."[15]

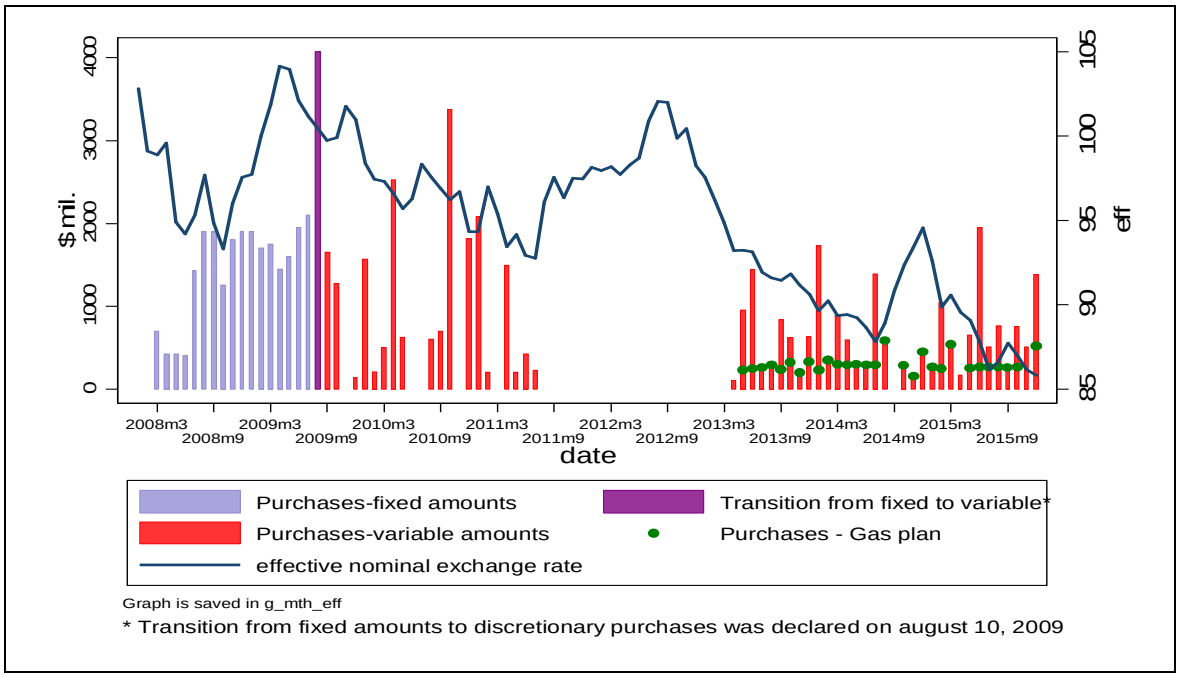
In early August 2009, in view of the appreciation trend in the shekel exchange rate, the BoI declared that from that time on, it would take action "in the event of unusual movements in the exchange rate which are inconsistent with underlying economic conditions, or when conditions in the foreign exchange market are disorderly."[16] In other words, the emphasis changed from describing the reason for the purchases by the need to increase the foreign currency reserves to responding to the state of the economy and the behavior of the foreign exchange market. Nevertheless, the BoI declared at the same time that it was "continuing its daily purchases of $100 million in the foreign exchange market." A few days later, on August 10, 2009, the Bank of Israel announced the end of purchases of a fixed amount. The Bank of Israel did not explicitly state what would guide it in determining the scope of its intervention in the market.[17]

Figure 1 describes foreign currency purchases starting in 2008 in millions of dollars, marking the purchases in the framework of the gas plan (in green). The substantial variance during the period can be seen, including a relatively long period in which the Bank of Israel did not actually intervene in the market. It is also clear that the volume of purchases until mid-2011 was usually larger than during the latter period, even taking into account the purchases in the framework of the gas plan. Although annual purchases in the framework of the gas plan were set and declared in advance at the annual level, their volume throughout the year was not constant.

[15] See the press release dated March 25, 2009.
http://www.boi.org.il/en/NewsAndPublications/PressReleases/Pages/090325e.aspx
[16] See the press release dated August 3, 2009.
http://www.boi.org.il/en/NewsAndPublications/PressReleases/Pages/090803f.aspx
[17] See the press release dated August 10, 2009.
http://www.boi.org.il/en/NewsAndPublications/PressReleases/Pages/090810e.aspx

Figure 1

Foreign Currency Purchases by the BoI, Monthly Frequency, Millions of Dollars, and the Effective Exchange Rate, March 2008-December 2015



The current analysis of BoI intervention in the foreign exchange market will refer to the period after August 10, 2009, (starting with monthly data from September 2009), when the BoI switched to foreign exchange purchases of varying amounts, at its discretion. Before then, the purchases were known and set in advance, and estimating the factors affecting the monthly quantities purchased in the short term is irrelevant. Furthermore, it is reasonable to assume that the mechanism for creating expectations and the behavior of the players in the market are different when the purchases are announced and known in advance.

Based on the Bank of Israel's statements, and similar to Adler and Tovar (2011)[18] and Adler, Lisack, and Mano (2015)[19], the factors tested for affecting the amount purchased are those that relate to the level of the foreign currency reserves and the appropriateness of the

[18] They include in the equation the lagged change in the exchange rate, the deviation of the real exchange rate from the equilibrium exchange rate, the lagged appreciation rate, the volatility of the exchange rate, and the lagged ratio of the reserves to the money supply and the debt.

[19] They include in the equation the lagged exchange rate, the ratio of the level of the balances to GDP or the money supply, the degree of dollarization of the deposits in the country, and measures of external shocks, such as VIX, interest rate differences, and additional variables.

exchange rate to the economic situation—in other words, indicators that are correlated with the degree to which the exchange rate deviates from the level believed to be consistent with underlying economic conditions.[20] In addition, we treat purchases in the framework of the gas plan separately. The equation was estimated with total purchases of foreign currency as the dependent variable, with the purchases in the framework of the gas plan as one of the explanatory variables, and in another version—the purchases excluding the gas plan. A detailed list of the variables included in the estimation is in the section below describing the estimation.

3. The Estimation

3.1 The Equation for Intervention in the Foreign Exchange Market

As described above, we estimate foreign currency purchases by the central bank, using instrumental variables. The dependent variable is the monthly volume of dollar purchases by the Bank of Israel, as published by the Bank.[21]

The equation is estimated in several specifications. The dependent variable is total foreign currency purchases[22] or foreign currency purchases excluding those in the framework of the gas plan. In addition, estimation of the probability of intervention in the framework of a logit model regardless of the scope of the intervention was tested for the first stage. Tests for over-identification and bias of the statistical inference in the first stage were employed.

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[20] See footnote 17.

[21] For example, see the Bank of Israel press release dated December 7, 2015, "Foreign Exchange Reserves at the Bank of Israel in November 2015," which includes information about the Bank of Israel's total purchases, and about the change in the reserves resulting from the purchases in the framework of the gas plan. (http://www.boi.org.il/en/NewsAndPublications/PressReleases/Pages/07-12-2015-ForexRes.aspx) Another press release, "Israel's Foreign Currency Market in November 2015," published on December 8, 2015, contains information about the development of the exchange rate, market volatility, and volume of the trading. (http://www.boi.org.il/en/NewsAndPublications/PressReleases/Pages/081215-FX.aspx)

[22] Because the estimation is over a short period, and also because to calculate the ratio of purchases to GDP it is necessary to multiply by the exchange rate, an endogenous variable, the estimation is for the nominal value of the purchases in dollars. Furthermore, in the framework of an analysis of supply and demand in the foreign exchange market in the short term, the absolute quantity of the purchases is the relevant amount.

Estimation of the Volume of the Intervention

Table 1a presents the results of the first stage of the estimation (Limited Information Maximum Likelihood—LIML), which includes, apart from the variables that appear in the exchange rate equation, (and are shadowed in the table), additional variables in order to identify the intervention. It appears that on the whole, the estimation is successful in tracking the volume of the intervention, although it does not succeed in completely reproducing the large purchases, mainly during the second part of the period (Figure 2). Although the estimated volume of intervention is not restricted to be zero or positive, the estimation succeeds in producing a very low (for some periods even negative) estimated value during the period in which there was no actual intervention. In other words, in general, the decision not to intervene during that period is compatible with the factors that explain the intervention during other periods.

The results indicate that the effect of each factor included in the estimation on the volume of the intervention is in the expected direction.[23]

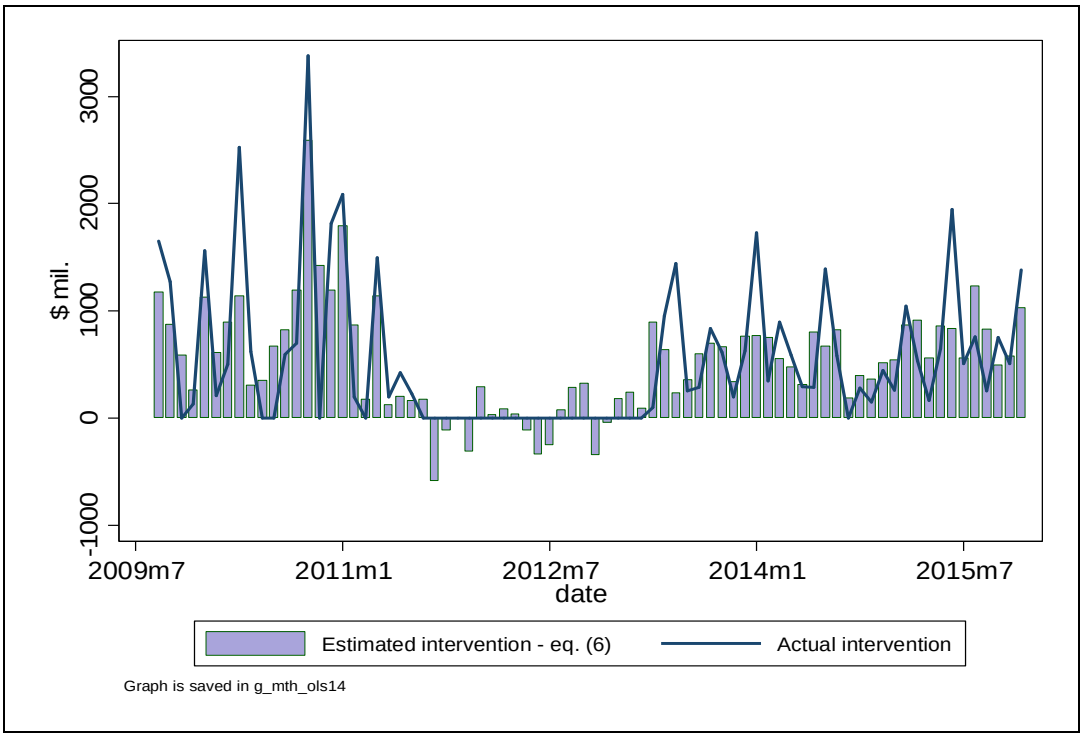
According to the various specifications, it appears that the Bank of Israel takes action to prevent the exchange rate from moving away from a level considered desirable. Various specifications indicate that a larger positive (depreciated) deviation of the real exchange rate from the long run equilibrium rate[24] (in the previous month) tends to reduce intervention (purchases) by the central bank. [25]

The level of foreign currency reserves also affects the volume of intervention. The effect of the reserves is significant, even though during the estimated period the incentive for purchasing foreign currency as it was officially described by the Bank, was no longer the need to increase the level of reserves.[26,27]

[23] Illustrations for the explanatory variables included in the estimation are displayed in Appendix 1.
[24] My thanks to Roni Frish for the data on the deviation of the real exchange rate from its long-term level. These figures are a result of his estimation of the long-term real exchange rate which is explained by the ratio of per capita GDP versus the US, the terms of trade, and the government weight in GDP. See Eckstein and Friedman (2010) for a methodological discussion of estimating the long-term exchange rate.
[25] A higher RE means a more depreciated real exchange rate.
[26] Because the variable of the ratio of the reserves to GDP is affected by the exchange rate, we used the reserves, measured in dollars, divided by GDP in fixed dollar terms in order to avoid an indirect effect of the shekel appreciation on this variable. See data in Appendix 1.
[27] See footnote 14.

Figure 2:

Actual Values and Estimated Values for Total Intervention by the Bank of Israel – Specification (6) in Table 1a



The development of the exchange rate in the previous month does not have a significant effect, but a dummy for an appreciation in the past month does have a significant positive effect on purchases in some of the specifications–partial evidence for "leaning against the wind" considerations of the central bank.

Capital inflows for direct investment in the economy (at a one-month lag) do not generally depend on differentials (between domestic and foreign interest rates), and can be considered as exogenous to the exchange rate, but they do contribute to pressure on the exchange rate to the extent that they are accompanied by the conversion of foreign currency into domestic currency. It was found that larger FDI inflows in the preceding month tend to significantly increase the scope of the intervention (in some of the specifications.) A larger interest rate differential between the Bank of Israel interest rate[28] and the US federal funds rate, which acts as an incentive for capital imports, is also correlated with a larger volume of intervention.

[28] The Bank of Israel interest rate for a given month is set in advance (in the last week of the preceding month), and therefore may be considered exogenous to the exchange rate developments during the current month.

We find that the economic situation affects the behavior of the central bank. An increase in exports can, a priori, have two effects on the volume of the intervention. A larger volume of exports increases the supply of foreign currency, boosts currency appreciation, and therefore may increase the desired intervention. Yet, at the same time, since one of the motivations for intervention is activity in the tradable sector, especially exports, the increase in exports reduces the need for intervention to support the shekel value of exports. According to the estimation, an increase in exports (in the previous year) has a negative impact on the volume of intervention—in other words, the second consideration outweighs the direct effect of an increase in exports on the foreign exchange market.

We also find in some of the specifications that a higher rate of 1-year (breakeven) inflation expectations tends to reduce the size of purchases by the central bank. Due to the pass-through from the development of the exchange rate to domestic prices, though only moderate, the higher the expected inflation is, the lower the incentive of the Bank to support additional depreciation of the shekel. This finding supports the idea that other objectives of the central bank, and in particular the inflation target framework according to which the Bank of Israel operates, influences the Bank's behavior in the forex market. Horvath (2006) finds, in the case of the Czech Republic, that the inflation target constrains the central bank's intervention.

The volume of trade in the market by nonresidents has a positive effect on the scope of intervention. The volume of purchases in the framework of the gas plan was found to have a significant, and not different from unity, effect on the total intervention in some of the specifications.

A valid instrumental variable must be correlated with the endogenous variable but uncorrelated with the errors (shocks) in the second-stage estimation. When the instrumental variables are "weak", the estimate obtained may be biased. We use an LIML estimator which may be superior to an ordinary 2SLS estimator (see Stock, Wright, and Yogo, 2002). We test the strength of the instrumental variables using the Partial R^2 statistic, describing the correlation between the endogenous variable (BoI purchases) and the additional identifying instrumental variables. We also look at the F-test for the additional instrumental variables—a significant value for the F-test indicates that the additional variables have explanatory power. Stock, Wright, and Yogo (2002) recommend a value higher than 10 in order to ensure useful instrumental variables for a single endogenous variable, but we are not able to achieve such a result. We test according to Stock and Yogo (2005) whether the instruments are weak. The

tests check whether a Wald test at the 5 percent level has an actual rejection rate of no more than 10 percent or 15 percent. For most of the specifications presented in Table 1a the value of the F-test indicates that the hypothesis of weak instruments with an actual rejection rate of more than 10 percent may be rejected. For some of the specifications, the actual rejection rate is not larger than 15 percent.

Figure 3 presents the annual cumulative estimated volume of intervention according to equation (6) in Table 1a, relative to actual volumes. As seen in the figure, the estimation depicts very closely the amounts purchased by the Bank, both in years of massive intervention, as in 2010, and in the period without intervention—as was during 2012.

Figure 3

Actual and Estimated Intervention According to Specification (6) in Table 1a, Annual Volume, 2009–15

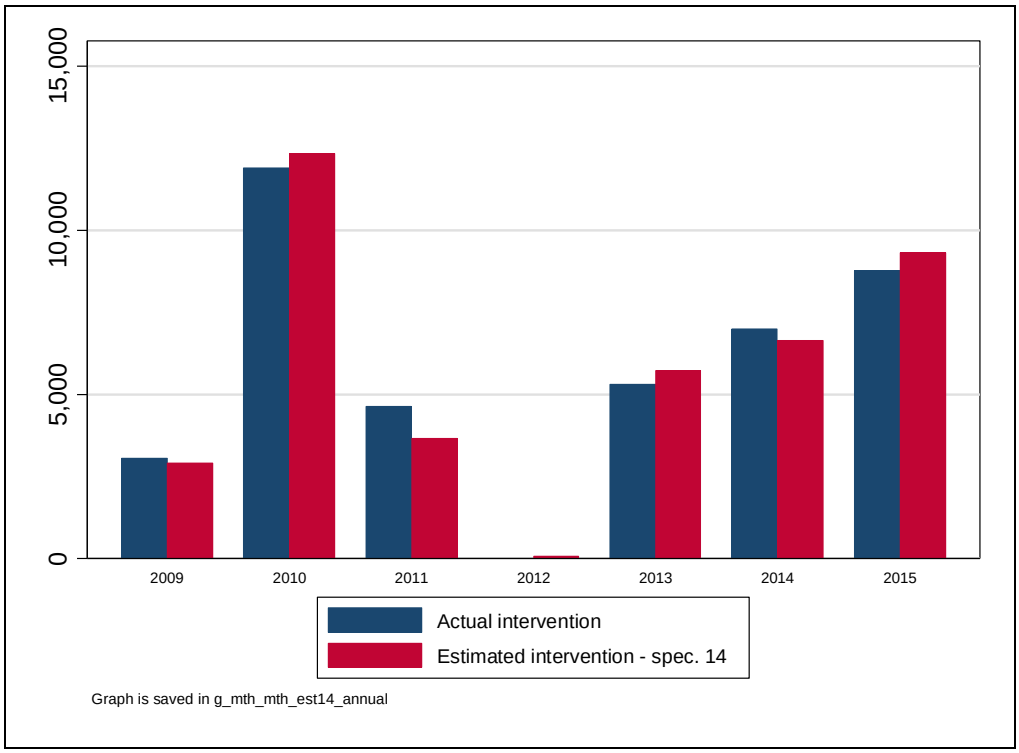


Figure 4

The Contribution of Identifying Variables to Explaining the Volume of the Intervention, According to Specification (6) in Table 1a

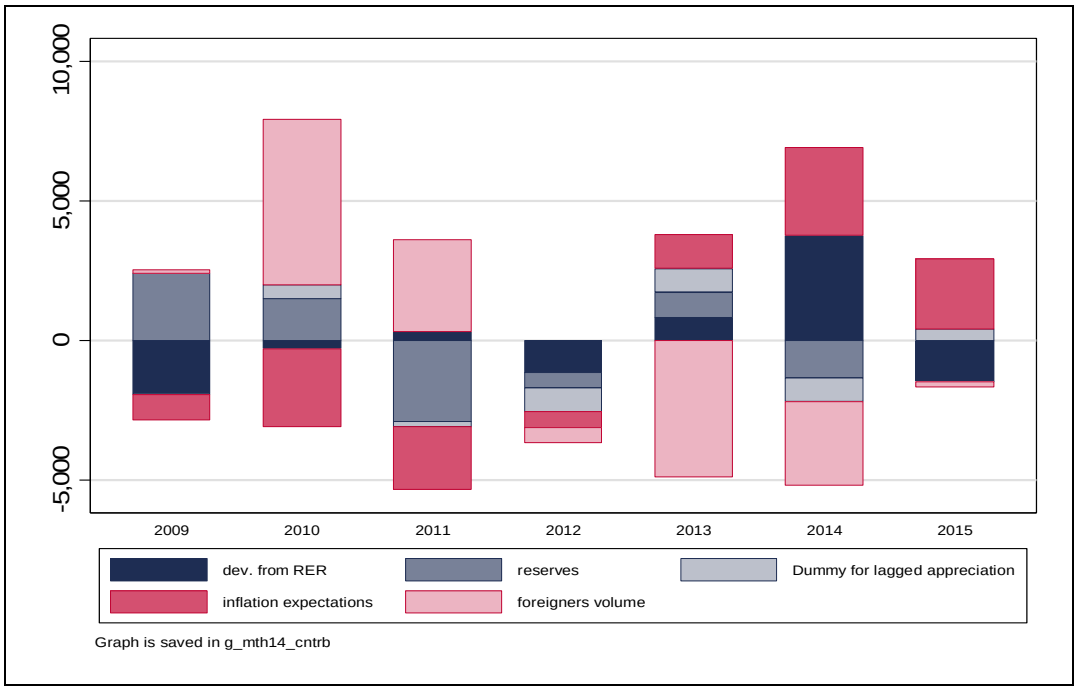


Figure 4 indicates the contribution of the identifying explanatory variables according to specification (6) in Table 1a.[29] The level of reserves contributed to increasing the purchases in the beginning of the period and its effect became negative later on when the level of reserves increased. In 2013, the level of reserves relative to GDP was lower, and therefore the contribution is positive. The volume of nonresidents' activity in the market (relative to the period's mean) was high in the first part of the period and therefore worked to increase the BoI's intervention in the market. In later years, the effect reversed. One year ahead inflation expectations that were higher than the inflation target range (1–3%) in the first years contributed to moderating the intervention, while in recent years, on the background of below-target inflation expectations, the Bank tended to increase the intervention to support depreciation of the exchange rate and its effects on the inflation rate.

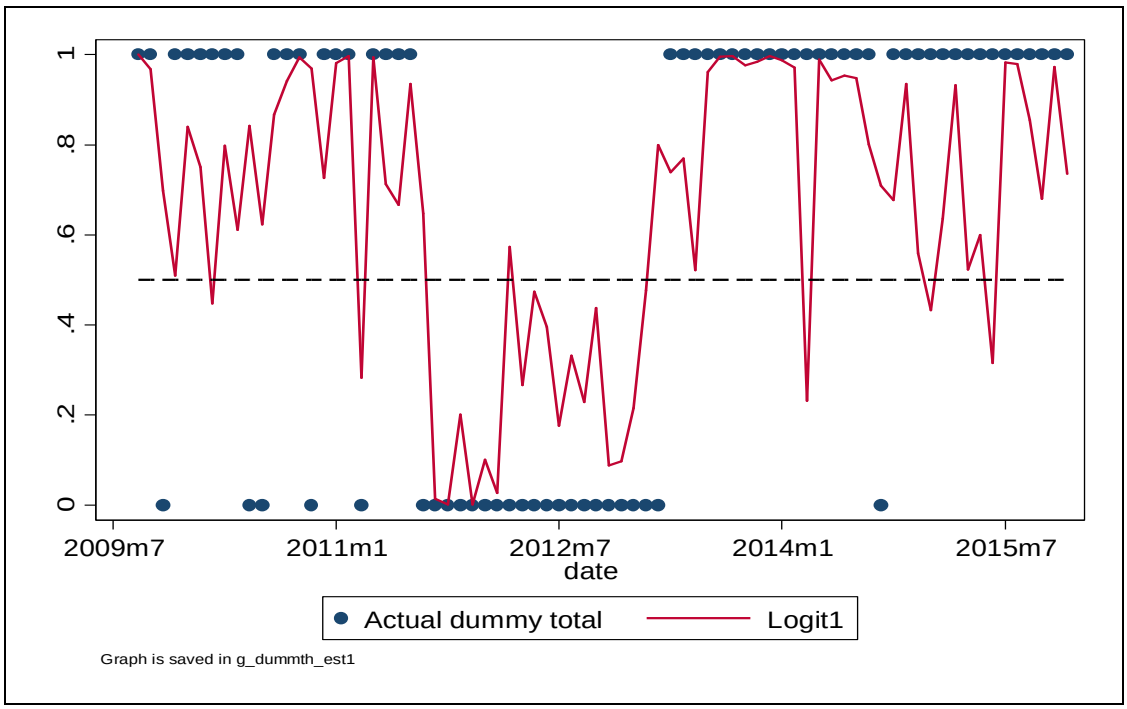
[29] The contribution of the variables is in terms of the deviation from their sample mean. The figure relates only to the identifying variables, i.e., the explanatory variables that do not appear in the second-stage exchange rate The set of identifying variables is very similar to that included in the estimation for the volume of intervention. The goodness of fit is evaluated using the ratio of correctly classified observations, which is the accuracy of the model. For all the specifications in Table 2a, more than 80 percent of observations are correctly classified.estimation.

Estimation of the Probability of Intervention

As an alternative approach, we estimated a first stage equation for the probability of intervention in the forex market in the framework of a Logit model. In the second stage equation for the rate of change in the nominal effective exchange rate, we included the estimated value for this probability. Table 2a and Figure 5 present the results of this estimation. The Logit specification estimates the log of the odds for intervention—log(odds) = P(intervene)/(1-P(intervene))—as a linear function of the explanatory variables.

Figure 5

Periods With or Without Intervention and the Estimated Probability According to Specification (1) in Table 2a, September 2009–December 2015



The set of identifying variables is very similar to that included in the estimation for the *volume* of intervention. The goodness of fit is evaluated using the ratio of correctly classified observations, which is the *accuracy* of the model.[30] For all the specifications in Table 2a, more than 80 percent of observations are correctly classified.

[30] An observation is said to be correctly classified if the estimated probability for intervention which is predicted is larger than 50 percent and the BoI actually intervened in that month, or if the probability is smaller than 50 percent and the Bank did not intervene.

As seen in Figure 5, the model fits relatively well the distinct periods with intervention—until July 2011 and from April 2013, as well as the period in between when the BoI did not intervene for a prolonged period.

The indication for "leaning against the wind" behavior by the central bank in this specification—which refers to the probability of intervening rather than to the volume of intervention—is stronger. The lagged change in the effective exchange rate or a dummy for appreciation in the previous month have a significant positive effect on the probability to intervene. A larger positive deviation of the exchange rate (excessive depreciation) and a larger level of foreign reserves, tend to lower the probability for intervention–similar to their effect on the volume of intervention. We also find that larger volatility of the exchange rate increases the probability of intervening. The economic environment, as manifested in the growth of world trade, and inflation expectations, have a negative effect on this probability.

The tests for the instrumental variables (displayed at the bottom of Table 2a) indicate that we can reject the hypothesis that the instruments are weak.

3.2 The Exchange Rate Equation

The equation is specified in terms of the monthly change in the (log) average nominal effective exchange rate. It is affected by variables related to the current account, those related to the capital account, and by the (estimated) characterization of the central bank's intervention in the market—estimated volume of intervention or the predicted probability of intervention. The estimation is for data beginning in September 2009, after the BoI declared it would intervene by discretion in the market, and until December 2015. The results are presented in Tables 1b and 2b.

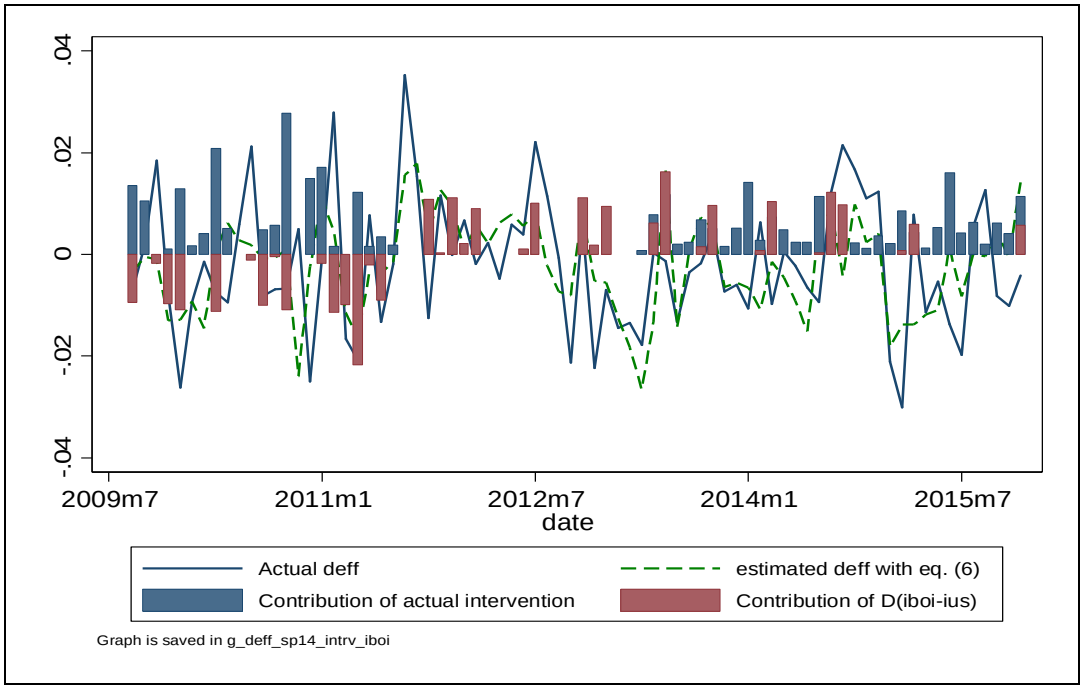
Generally, the estimated value of the change in the exchange rate follows the actual movements of the exchange rate, especially during the first part of the analyzed period, and to a lesser extent in the last few years. The contribution of the estimated intervention to the depreciation of the exchange rate is substantial (Figure 6).

According to the estimations presented in Table 1b, the intervention by the Bank of Israel contributes significantly to the rate of depreciation of the exchange rate. For every $100 million of intervention, the exchange rate depreciates by an extra 0.07–0.09 percentage points. The monthly volume of purchases in the period in which the Bank of Israel actually

intervened in the market averaged approximately $830 million (about one-third of one percent of GDP). According to the estimation results, such intervention makes the deprecation in the effective exchange rate 0.6 percent larger, compared with a month with no intervention. In terms of percentages of GDP, intervention of the size of one percent of GDP increases depreciation by about 1.8 percent.

Figure 6

The Actual and Estimated Change in the Effective Exchange Rate According to Specification (6) in Table 1b, and the Direct Contribution of the Intervention and the Change in the BoI Interest Rate, September 2009–December 2015



It is interesting to compare the contribution of the intervention to the rate of change of the exchange rate, relative to that of the interest rate, which is the major instrument of monetary policy. The coefficient of the change in the interest rate[31] in the exchange rate equation indicates that a 0.25 percentage point reduction in the interest rate is expected to depreciate the effective exchange rate by approximately an additional 1%. Figure 6 displays the

[31] The variable in the equation is the change in the interest differential between the BoI interest rate and the Fed interest rate. However, the Fed's interest rate is constant at 0–0.25 percent during the whole period examined (except for a 0.25 percentage point increase in the middle of last month of the sample—December 2015).

contribution of the actual intervention and actual change in the interest rate to the rate of change in the exchange rate. Until mid-2011 the two instruments—intervention and interest rate—worked in opposite directions in similar magnitudes. Later, when the Bank did not actually intervene in the market, the interest rate reductions contributed to the depreciation (or smaller appreciation) of the exchange rate. In the last part of the period, both intervention and the accommodative monetary policy worked in the same direction.

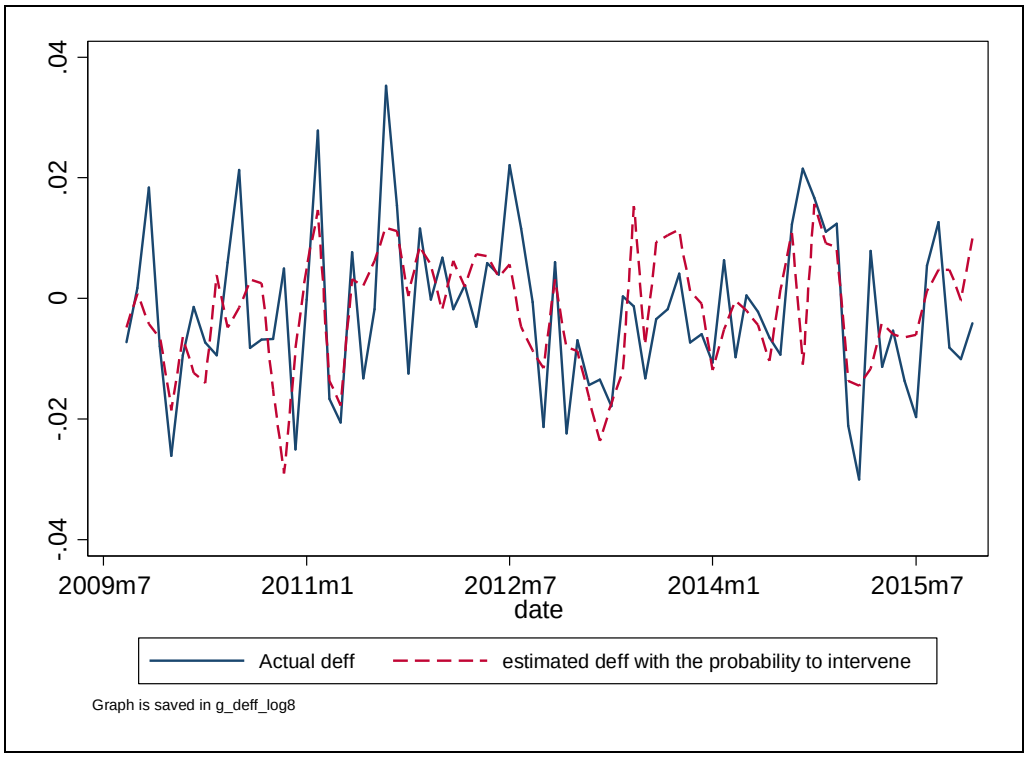
According to the estimation framework presented earlier, among the factors explaining the rate of change in the (log of the) exchange rate are those affecting the current account. The lagged 3-month average surplus in the current account works to moderate the depreciation of the exchange rate, as it increases the supply of foreign currency in the market. FDI inflows, which may be generally considered as exogenous to the short-term developments in the exchange rate, tend to also moderate depreciation of the exchange rate. The demand for short-term financial investment in the domestic market is represented by the change in the short-term interest rate differential between the Israel and the US, and has the expected significant negative sign. A higher perceived country risk, as measured by the 5-year CDS spread, tends to increase depreciation. A larger rate of change in global stock markets contributed to the appreciation of the domestic currency, possibly due to larger volume of capital inflows to Israel (and other countries) against the background of a favorable global economic environment. The cross-rate between the dollar and other currencies has a marginally negative effect.

Table 2b presents the results for the second stage based on the estimated *probability* of intervention. The explanatory variables and their contributions are similar to those in the specification with the estimated volume of intervention described above. The average value of the estimated probability to intervene, for the period when the Bank intervened (i.e., excluding August 2011–March 2013), is about 0.75-0.80, according to the various specifications. Therefore, the implication of a coefficient of 0.015 to 0.018 is depreciation larger by about 1.1–1.4 percentage points in a month with intervention compared to a month without intervention—a somewhat larger effect than that obtained using the estimated volume of intervention (0.6).

Figure 7 shows the actual and estimated rate of change in the exchange rate, based on a specification including the probability to intervene as the first stage estimator. The fit is fairly good and very similar to that obtained by using the estimated volume of intervention for the first stage.

Figure 7

The Actual and Estimated Change in the Effective Exchange Rate According to Specification (6) in Table 2b, September 2009–December 2015



The Cumulative Effect of Intervention

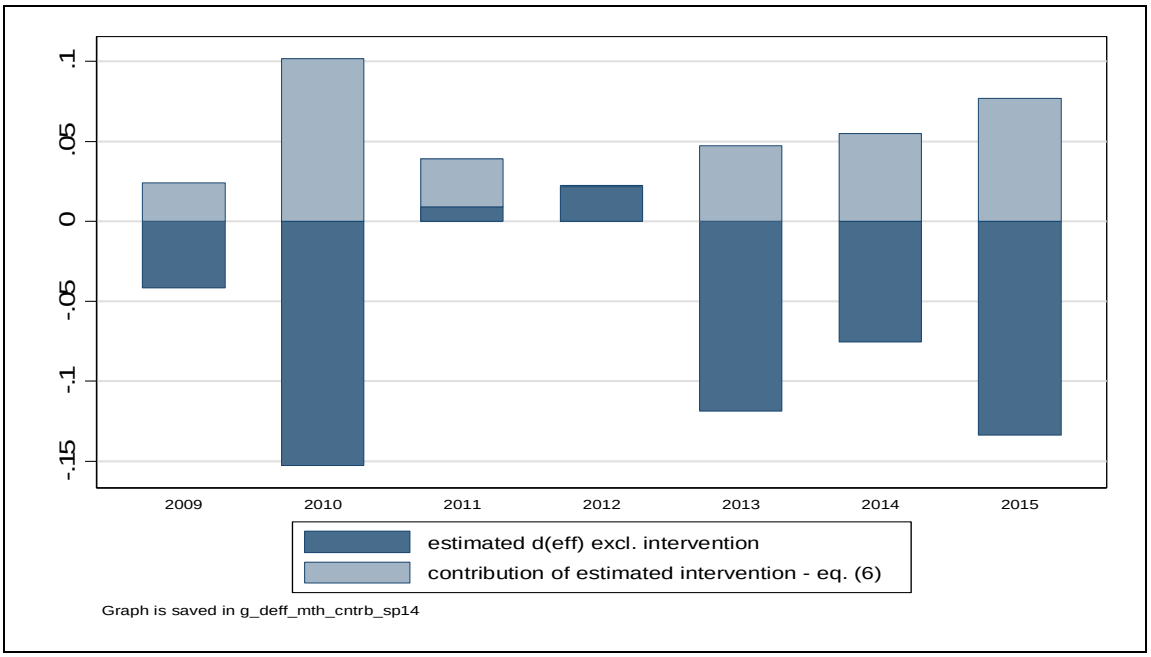
Applying the estimation's results for the intervention's contribution to the exchange rate, we may evaluate the annual cumulative effect of the central bank's purchases. This summation assumes that the change in the exchange rate due to the intervention is permanent and is not eroded in the subsequent periods. This is a strong assumption. Therefore, the estimate is an upper limit to the effect of the intervention.

In order to evaluate a possible erosion of the effect of intervention, we included in the second stage estimation, in addition (or as an alternative) to the contemporaneous volume of estimated intervention, the lagged volume of estimated intervention. However, due to high

autocorrelation (0.6–0.7) in the estimated (and actual) volume of intervention, when the lagged value was included, the contemporaneous intervention lost its significance, while the impact of the lagged intervention was positive and significant. An alternative specification with instrumental variables for the mean intervention in the current and lagged month produces similar results to those of the basic specification—a significant coefficient of a similar size—suggesting that the erosion of the intervention's impact is small.

Figure 8

The Annual Contribution of Estimated Intervention to the Change in the Exchange Rate, According to Equation (6) in Table 1b, 2009–15



According to Figure 8, the intervention offset a substantial share of the forces that worked to appreciate the domestic currency during those years. According to the estimation, during the period when the Bank did not actually intervene, there did not exist forces for appreciation, as represented by the estimation.

Estimating for Intervention Excluding the Gas Program

Since mid-2013, the Bank of Israel has purchased foreign currency as part of a program to offset the effect of natural gas production in Israel on the exchange rate. The volume of annual purchases within this program is announced in advance each year by the Bank of

Israel. The actual volume of purchases is reported on a monthly basis in the month following the intervention. The purchases during the year are not constant, but nonetheless do not vary dramatically between months (see Figure 1). A priori it is hard to tell whether these purchases should be treated as other discretionary purchases, and their effect on the exchange rate will be similar to that of other purchases, or, because they are known in advance, the effect of the actual purchases will be insignificant.

The basic specifications that were presented above referred to the total amount of purchases as the first-stage estimated variable, while the gas program purchases were included as an explanatory variable in some of the specifications with a coefficient not different from unity.

An alternative approach, presented in Tables 3a and 3b, estimates the effect of the intervention on the exchange rate excluding that of the gas program. The results are similar, although the results of tests for weak variables are marginal. The estimated effect of the purchases excluding the gas program is very similar to that obtained in the baseline specification.

We may conclude from this exercise that although purchases within the gas program were declared in advance (on an annual basis), their effect is similar to that of other purchases due to the fact that the volume of the gas-program purchases is not fully known in advance on a monthly basis.

4. Estimating for Subperiods

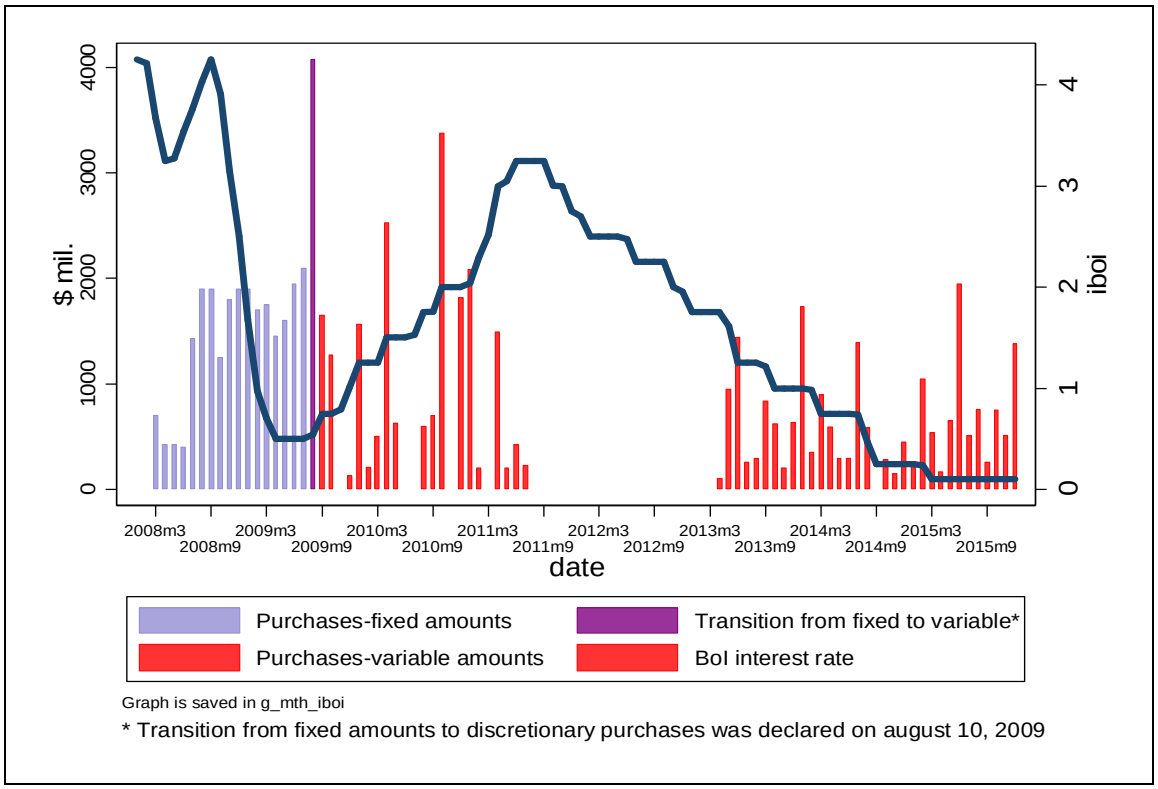
The estimation of the factors affecting the evolution of the exchange rate and the first-stage estimation for the intervention of the Bank of Israel were carried out for the period starting September 2009, when the BoI switched to discretionary intervention, until December 2015. Although the period analyzed is quite short, we investigate—to the extent possible—the stability of the links between the variables describing the foreign exchange market. The two-stage system is estimated for a number of subperiods. The entire period is divided into segments characterized by the nature of intervention: until July 2011 and from April 2013 actual positive intervention in the market, and in between those dates, zero actual intervention. The cutoff point of July 2011 also identifies a reversal in monetary policy, from

an upward trend in the interest rate to an accommodative monetary policy, with the interest rate declining from 3.25 percent to as low as 0.1 percent (Figure 9).

Tables 4a and 4b present the results of the estimation for different subsamples. On the whole, the results for the shorter samples are weaker, presumably due to the very small number of observations in the partial samples. Nonetheless, the only subsample for which the effect of the intervention is significant is that of the second part of the sample—starting in September 2011, including the period when the BoI did not actually intervene in the market.

Figure 9

The Bank of Israel Purchases and the BoI Interest Rate, 2008–15



Two possible complementary conclusions may be drawn (very carefully) from these results. The first is that intervention is more effective when it is accompanied by an accommodative interest rate policy, as was the case in the second half of the period. There is an ability to signal to the market by intervention that the policy is and will be accommodative, and its credibility is greater when the interest rate policy works in the same direction as the

intervention in the foreign exchange market. (See also Flug and Shpitzer, 2011 for Israel and Kamil, 2008 for Colombia).[32]

The second conclusion is drawn from the fact that omitting the period without intervention (column (6) versus column (1) in Table 4b) makes intervention essentially insignificant. This result suggests that the signaling factor is fundamental and that the important indication is whether the Bank is acting in the market or not, and to a lesser extent the volume of intervention. This interpretation is also in line with the stronger results we obtained when using the (estimated) probability that the Bank will intervene, rather than the exact volume of intervention in our estimation. The notion that intervention works mainly through the signaling channel is also described by Kaminsky and Lewis (1996), who show that only when monetary policy is consistent with intervention (i.e., accommodative policy alongside purchases of foreign currency) is the effect of intervention on the exchange rate in the expected direction.

5. Concluding Remarks

Intervention by the central bank in the foreign exchange market is a monetary policy instrument used by many countries around the world, in the past and present. The Bank of Israel has been intervening in the foreign exchange market since March 2008 after not doing so for over a decade. However, only very few studies concerning the effect of the intervention on the exchange rate in Israel have been published to date.

The objective of this paper is to assess whether, and by how much, the intervention by the central bank affects the nominal exchange rate. In order to do so, and as a by-product of the analysis, we suggest a description of the factors influencing the volume of the intervention.

A key difficulty in estimating the effect of the intervention on the exchange rate is the endogeneity of the intervention–the decision to intervene (purchase) depends on the evolution of the exchange rate. We estimate the factors affecting the monthly rate of change in the effective nominal exchange rate of the shekel, with the intervention being one of the factors.

[32] Kamil (2008) examined the effectiveness of intervention in the exchange market in Colombia, using daily data, and found that intervention aimed at moderating the appreciation of the domestic currency was more effective when monetary policy worked in the same direction—namely, was expansionary.

In order to overcome the endogeneity of the intervention we use instrumental variables for the intervention in a two-stage estimation framework.

The main results obtained in this study are that the intervention conducted since mid-2009 contributed to the depreciation of the nominal effective shekel exchange rate, at least in the same month. The estimated effect of intervention is positive and significant for various specifications of the instruments. We find that an increase of $100 million in the monthly intervention is expected to accelerate the depreciation rate by 0.07–0.09 percentage points in that month. According to the estimation results, the average volume of monthly intervention during the period examined—about $830 million—contributed to depreciation in the effective exchange rate that is 0.6 percent larger than a month with no intervention. Estimating the effect on the exchange rate using a variable describing the probability of intervention in the market each month yields a higher effect, with the effective exchange rate depreciation larger by about 1.1–1.4 percent, compared with a month with no intervention. The magnitude is, according to the estimation, similar to the effect of a 0.25 percentage point reduction in the Bank of Israel's interest rate on the exchange rate.

These results are consistent with the hypothesis that intervention has an effect through the signaling channel, not only through its impact on the portfolio. In addition, results of estimation for subperiods support the hypothesis that the effect of intervention is larger when it occurs together with an accommodative interest rate policy, in contrast to a situation in which the interest rate policy is working in the opposite direction.

Apparently, the estimated volume of intervention may have been expected by market participants, and therefore should have been already incorporated into the price of foreign currency so that we could not have detected any effect of the estimated intervention on the exchange rate. The results indicate that this is not the case. It may be that the public does not possess the same real time information as the central bank or, more likely, does not know the intervention function of the central bank. In intervening, the central bank signals and reiterates its intention to keep monetary policy accommodative. The estimation describes in retrospect the factors that affect the central bank's intervention on a monthly basis, from a macroeconomic perspective. The specific daily volume of intervention, which is not known in advance to the public, may still have an effect on the exchange rate, as was found here.

The volume of intervention estimated in the first stage generally succeeds in following the actual volume of intervention, including the months in which there was no actual intervention (from August 2011 to March 2013). The ratio of the foreign exchange reserves to GDP contributes to the explanation of the intervention. The significant effect of the deviation from the equilibrium real exchange rate indicates that this consideration also guides the central bank. A negative effect of an increase in exports on the scope of intervention indicates that support for the exporting sector is also among the considerations for intervention. A negative coefficient for the (lagged) exchange rate and a positive contribution of the standard deviation of the exchange rate (in some of the specifications) are consistent with the "leaning against the wind" approach.

The importance of understanding the effectiveness and usefulness of intervention in the foreign exchange market as an additional instrument of monetary policy, and at the same time the challenge in identifying it due to its endogeneity, call for further investigation of the issue in order to establish and confirm the results obtained in this study.

Table 1a: First-stage estimation of foreign exchange purchases, 9/2009-12/2015

Equation	(1)	(2)	(3)	(4)	(5)	(6)
Δ(BoI – US federal funds rate differential) [#]	1.03**	1.19**	1.51**	1.30**	1.14**	1.17**
Δ (dollar-currency basket exchange rate, [dxy]) [#]	-5.3	-4.7	-3.6	-5.3	-4.7	-9.5**
Δ (Israel's 5-year CDS index) #	-1.22	-1.12	-0.61	-0.38	-0.58	-0.43
FDI capital inflow	0.09*	0.09*	0.07	0.09	0.04	0.09*
Δ (MSCI index, 3-months average) [#]	2.62	2.90	7.75*	8.57**	9.51	7.26*
L.(current account, 3-months average) [#]	47.2**	53.8**	49.1**	41.7*	46.7**	34.2
Purchases in the framework of the gas program	0.42		0.93*	1.10**	1.18**	
L.(Deviations from the real exchange rate equilibrium, 3-month average) [#]	-8.8**	-10.5***	-6.12*	-5.54*	-5.32	-9.09***
L.(Forex reserves to GDP at a fixed exchange rate, deviation from sample mean) [#]	-9.5	-9.9	-12.95**	-11.84**	-11.9*	-13.2**
L.Δ(effective exchange rate).		-8.4				
L.(Dummy for negative change in the effective exchange rate).	296.4		217.3	229.2*		338.0**
L.(FDI capital inflow, 3-month average, deviation from sample mean), lagged			0.14*		0.09	
Volume of foreign currency trading by foreigners, deviation from sample mean	0.58***	0.53***	0.48***	0.42***	0.44***	0.56***
L.(The change in export volume, 12-month average). [#]	-45.7**	-49.4***				
L.(change in the 12-months inflation rate)			-290.6	-183.5		
1 year break-even inflation expectations						-356.4***
Const.	2414	2660	-387.5*	-385.7*	3223*	4046**
Adj. R^2	0.46	0.44	0.45	0.43	0.41	0.47
Partial R^2	0.33	0.29	0.32	0.29	0.25	0.33
Min. eigenvalue stat. (F) (p-value)	5.07 (0.00)	5.22 (0.00)	4.24 (0.00)	4.33 (0.00)	4.34 (0.00)	6.37 (0.00)
F for weak instr. (LIML)	4.45/3.34	4.84/3.56	4.18/3.18	4.45/3.34	4.84/3.56	4.84/3.56
p-value for overidentification	0.37	0.27	0.64	0.81	0.79	0.71

[#] Coefficient divided by 1,000. * Significant with 10%, ** 5%, *** 1%.

L. = lagged 1-month; Δ=Delta log, difference for interest rates

Table 1b: Instrumental variables LIML estimation of rate of change in the nominal effective exchange rate, 9/2009-12/2015

Equation	(1)	(2)	(3)	(4)	(5)	(6)
Estimated intervention ^	0.0075*	0.0075[&]	0.0070*	0.0082*	0.0090*	0.0082**
Δ(BoI – US federal funds rate differential)	-0.044***	-0.044***	-0.044***	-0.045***	-0.046***	-0.045***
Δ (dollar-currency basket exchange rate, [dxy])	-0.14*	-0.14*	-0.14*	-0.14*	-0.13	-0.14*
Δ (Israel's 5-year CDS index)	0.08***	0.08***	0.08***	0.08***	0.08***	0.08***
FDI capital inflow ^	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
Δ (MSCI index, 3-months average)	-0.26***	-0.26***	-0.25***	-0.26***	-0.27***	-0.27***
L.(current account, 3-months average)	-1.55***	-1.55***	-1.52***	-1.62***	-1.67***	-1.62***
Const.	0.017	0.017	0.017	0.018	0.018	0.017
R^2	0.24	0.24	0.25	0.21	0.18	0.21
RMSE	0.0113	0.0113	0.0112	0.0115	0.0117	0.0115

[^] Coefficient multiplied by 1,000. [#] coefficient divided by 1000. * Significant with 10%, ** 5%, *** 1%, &-p-value is 0.11

L. = lagged 1-month; Δ=Delta log, difference for interest rates. A positive change in the exchange rate=depreciation

Table 2a: First-stage Logit estimation of probability of intervention, 9/2009-12/2015

Equation	(1)	(2)	(3)	(4)	(5)	(6)
L. Δ (effective nominal exchange rate)	-124.6***	--124.6***	-95.2***			-75.3**
L.(Dummy for appreciation larger than 1%)				2.9***	2.6***	
Δ(BoI – US federal funds rate differential)	11.6***	12.0***	7.24**	11.1***	6.4**	
L.(Deviations from the real exchange rate equilibrium, 3-month average) #	-98.0***	-98.4***	-70.2***	-95.3***	-72.5***	-58.2***
L.(Forex reserves to GDP at a fixed exchange rate, 3-month average) #	-88.4*	-89.3**				-72.9***
L.(Forex reserves to GDP at a fixed exchange rate, 6-month average) #			-61.6**	-143.8***	-79.0***	
L.monthly standard deviation of effective exchange rate	664.0**	666.1**	632.5**			
Volume of foreign currency trading by foreigners, deviation from sample mean		-.0003				
L. Δ (goods exports, 12-months average)	-97.3*	-89.0			-63.6	
L. Δ (world trade index, 3-months average)				-123.7***		
1 year break-even inflation expectations						-1.55***
Const.	22.3**	22.5**	14.79**	39.9***	21.5***	23.2***
Correctly classified	0.84	0.83	0.83	0.81	0.83	0.79
Pseudo R^2	0.39	0.39	0.36	0.43	0.33	0.31
Partial R^2	0.25	0.24	0.19	0.22	0.20	0.27
Min. eigenvalue stat. (F) (p-value)	23.0 (0.00)	21.7 (0.00)	16.2 (0.00)	19.5 (0.00)	17.3 (0.00)	24.6 (0.00)
F for weak instr. (LIML)	16.38/8.96	16.38/8.96	16.38/8.96	16.38/8.96	16.38/8.96	16.38/8.96

* Significant with 10%, ** 5%, *** 1%

L. = Lagged 1-month; Δ=Delta log, difference for interest rates

Table 2b: Instrumental variables 2SLS estimation of rate of change in the nominal effective exchange rate, 9/2009-12/2015

Equation	(1)	(2)	(3)	(4)	(5)	(6)
Estimated probability of intervention (IV) ^	0.018**	0.018**	0.020**	0.011[&]	0.016**	0.014**
Δ(BoI – US federal funds rate differential)	-0.05***	-0.05***	-0.05***	-0.04***	-0.05***	-0.04***
Δ (dollar-currency basket exchange rate, [dxy])	-0.21**	-0.21**	-0.21*	-0.20**	-0.20**	-0.20**
Δ (Israel's 5-year CDS index)	0.07***	0.07***	0.07**	0.07***	0.07***	0.07***
FDI capital inflow ^	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
Δ (MSCI index, 3-months average)	-0.27***	-0.27***	-0.28***	-0.24***	-0.26***	-0.25***
L.(current account, 3-months average)	-2.47***	-2.50***	-2.71***	-1.92**	-2.34**	-2.13**
Const.	0.017***	0.017***	0.017**	0.016**	0.017**	0.017**
R^2	0.12	0.11	0.03	0.17	0.17	0.23
RMSE	0.0121	0.0122	0.0127	0.0109	0.0118	0.0113

[^] Coefficient multiplied by 1,000. * Significant with 10%, ** 5%, *** 1% , $- p-value is 0.16. &-p-value is 0.12.

L. = Lagged 1-month; Δ=Delta log, difference for interest rates. A positive change in the exchange rate=depreciation.

Table 3a: First-stage estimation of foreign exchange purchases excl. gas program, 9/2009-12/2015

Equation	(1)	(2)	(3)	(4)	(5)
Intervention according to the gas program	0.10	0.18	0.25	0.17	0.10
Δ(BoI – US federal funds rate differential) [#]	1.30**	1.14**	1.10**	1.18**	0.62
Δ (dollar-currency basket exchange rate, [dxy]) [#]	-5.30	-4.76	-4.96	-5.17	-5.66
Δ (Israel's 5-year CDS index) #	-0.38	-0.58	-0.48	-0.50	0.78
FDI capital inflow	0.10	0.04	0.09	0.08	0.07
Δ (MSCI index, 3-months average) [#]	8.57**	6.51	7.45*	5.63	9.54**
L.(current account, 3-months average) [#]	41.7*	46.7**	46.0**	38.1	59.6**
L. Δ (effective nominal exchange rate)				-6.46	
Δ.(6m. yield-BoI interest rate) [#]					-1.49*
L.(Deviations from the real exchange rate equilibrium, 3-month average) [#]	-5.54*	-5.32	-4.85	-5.85*	-3.74
L.(Forex reserves to GDP at a fixed exchange rate, deviation from sample mean) [#]	-11.8**	-12.0**	-11.2*	-12.0**	-10.7*
L.(Dummy for negative change in the effective exchange rate).	229.2*				
L.(FDI capital inflow, 3-month average, deviation from sample mean), lagged		0.09			
L. Δ(12-months inflation rate) [#]	-183.5				
Volume of foreign currency trading by foreigners, deviation from sample mean	0.42***	0.44***	0.43***	0.42***	0.47***
L. Δ(GDP, 3-months average)					-90.0**
Const.	-385.8*	3223*	2875	3183*	2959*
Adj. R^2	0.41	0.39	0.39	0.39	0.42
Partial R^2	0.28	0.23	0.21	0.23	0.28
Min. eigenvalue stat. (F) (p-value)	4.00 (0.00)	4.83 (0.00)	5.87 (0.00)	4.77 (0.00)	5.01 (0.00)
F for weak instr. (LIML)	4.45/3.34	5.44/3.87	6.46/4.36	5.44/3.87	4.84/3.56
p-value for overidentification.	0.76	0.64	0.45	0.63	0.27

[#] Coefficient divided by 1,000. * Significant with 10%, ** 5%, *** 1%.

L. = Lagged 1-month; Δ=Delta log, difference for interest rates

Table 3b: Instrumental variables LIML estimation of rate of change in the effective nominal exchange rate (IV for purchases excl. gas program), 9/2009-12/2015

Equation	(1)	(2)	(3)	(4)	(5)
Estimated intervention (excluding. gas program) ^	0.0079*	0.0088*	0.0093*	0.0100*	0.0095*
Intervention according to gas program		0.0010	0.0010	0.0010	0.0010
Δ(BoI – US federal funds rate differential)	-0.048***	-0.045***	-0.046***	-0.047***	-0.046***
Δ (dollar-currency basket exchange rate, [dxy])	-0.14*	-0.13	-0.13	-0.13	-0.13
Δ (Israel's 5-year CDS index)	0.08***	0.08***	0.08***	0.08***	0.08***
FDI capital inflow ^	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
Δ (MSCI index, 3-months average)	-0.26***	-0.27***	-0.28***	-0.28***	-0.28***
L.(current account, 3-months average)	-1.43***	-1.68***	-1.71***	-1.76***	-1.72***
Const.	0.017***	0.018***	0.018***	0.018***	0.018***
R^2	0.21	0.19	0.17	0.13	0.16
RMSE	0.0115	0.0117	0.0118	0.0120	0.0119

^ Coefficient multiplied by 1,000. * Significant with 10%, ** 5%, *** 1%

L. = Lagged 1-month; Δ=Delta log, difference for interest rates. A positive change in the exchange rate=depreciation.

Table 4a: First-stage estimation of Foreign exchange purchases – by periods, According to eq. (1) in Table 1a, 9/2009-12/2015

Equation	(1)	(2)	(3)	(4)	(5)	(6)
Period	2009.9-2015.12	2009.9-2011.7	2009.9-2013.3	2013.4-2015.12	2011.8-2015.12	2009.9-2011.7 & 2013.4-2015.12
No. of observations	76	23	43	33	53	56
Δ(BoI – US federal funds rate differential) [#]	1.03**	3.04**	1.59**	-1.19	-0.21	1.48*
Δ (dollar-currency basket exchange rate, [dxy]) [#]	-5.3	-9.9	-2.5	-4.6	-4.0	-6.9
Δ (Israel's 5-year CDS index) [#]	-1.22	-1.85	-2.40*	2.45	0.88	-1.22
FDI capital inflow	0.09*	-0.29*	0.02	-0.01	0.09*	0.09
Δ (MSCI index, 3-months average) [#]	2.62	16.7	-2.53	0.52	-0.39	10.0
L.(current account, 3-months average) [#]	47.2**	238.0*	-13.3	44.7	26.8	126.1**
Purchases in the framework of the gas program	0.42	--	--	0.79	1.22**	0.51
L.(Deviations from the real exchange rate equilibrium, 3-month average) [#]	-8.8**	-37.9	5.9*	4.1	-18.6	-12.2**
L.(Forex reserves to GDP at a fixed exchange rate, deviation from sample mean) [#]	-9.5	-12.3	-6.58	-12.3	-1.62	-10.0
L.(Dummy for negative change in the effective exchange rate).	296.4	334.1	370.0**	187.5	64.5	240.5
Volume of foreign currency trading by foreigners, deviation from sample mean	0.58***	1.09***	1.00***	-0.16	-0.12	0.64***
L.(The change in export volume, 12-months average). #	-45.7**	-144.8**	-362.7	38.5	-5.52	-61.5**
Const.	2414	1543	2033	3415	160.9	1738
Adj. R^2	0.46	0.69	0.64	-0.03	0.40	0.35
Partial R^2	0.33	0.72	0.54	0.14	0.26	0.31
Min. eigenvalue stat. (F) (p-value)	5.07 (0.00)	5.74 (0.00)	7.33 (0.01)	0.55 (0.77)	2.58 (0.05)	3.23 (0.01)
F for weak instr. (LIML)	4.45/3.34	4.84/3.56	4.84/3.56	4.45/3.34	4.45/3.34	4.45/3.34
p-value for overidentification.	0.37	0.08	0.07	0.44	0.14	0.33

[#] Coefficient divided by 1,000. * Significant with 10%, ** 5%, *** 1%

L. = Lagged 1-month; Δ=Delta log, difference for interest rates

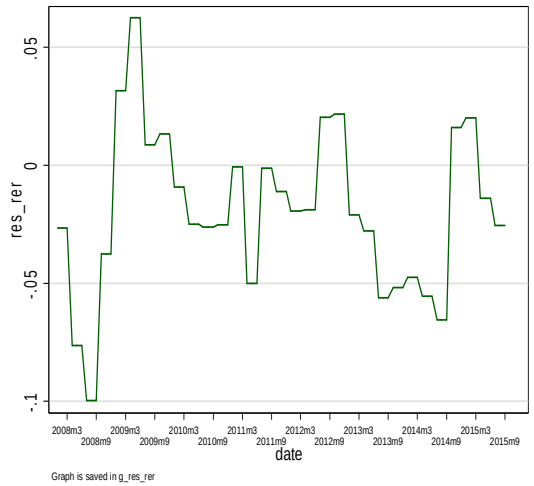
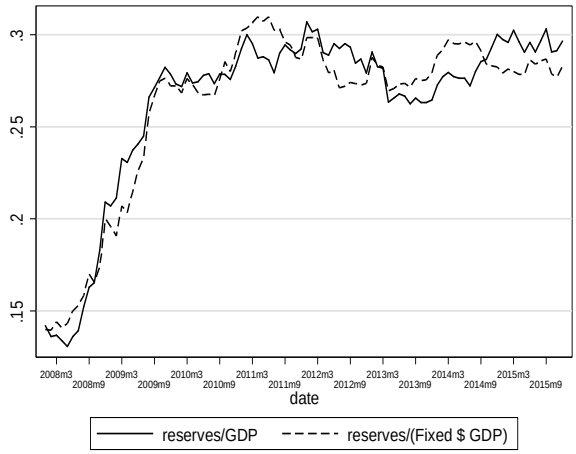
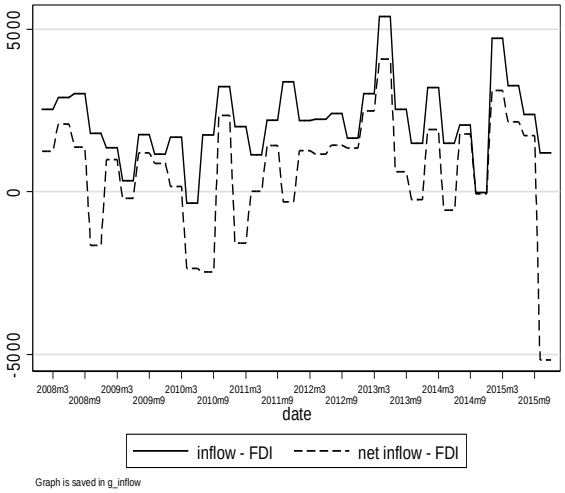
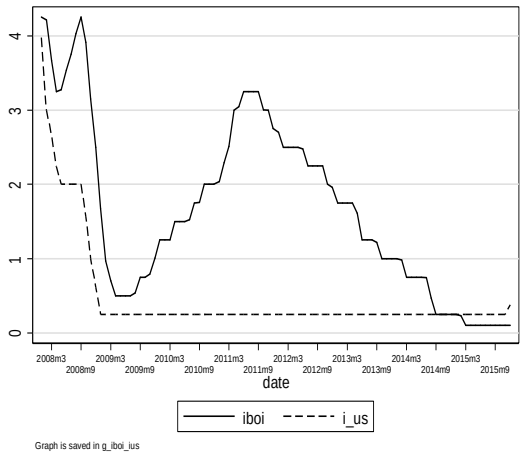
Table 4b: Instrumental variables LIML estimation of rate of change in the effective nominal exchange rate – by periods, 9/2009-12/2015

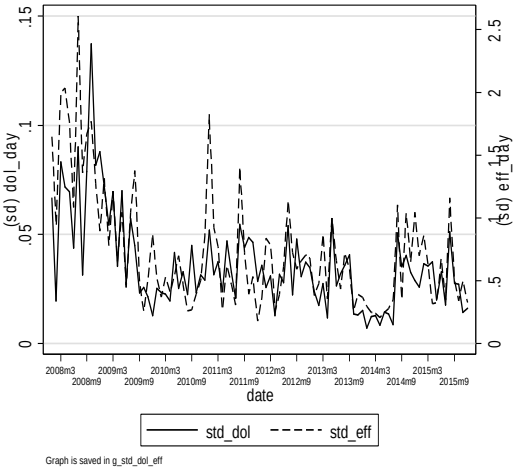
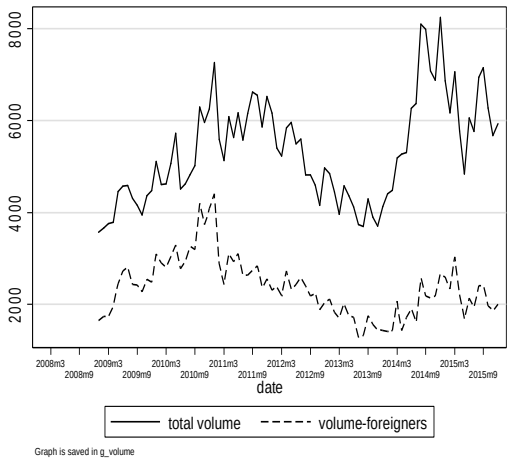
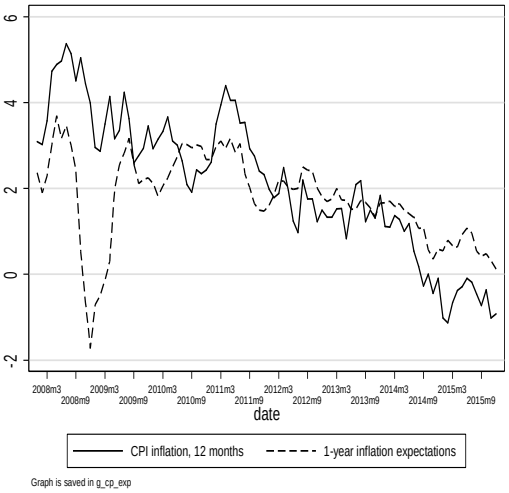
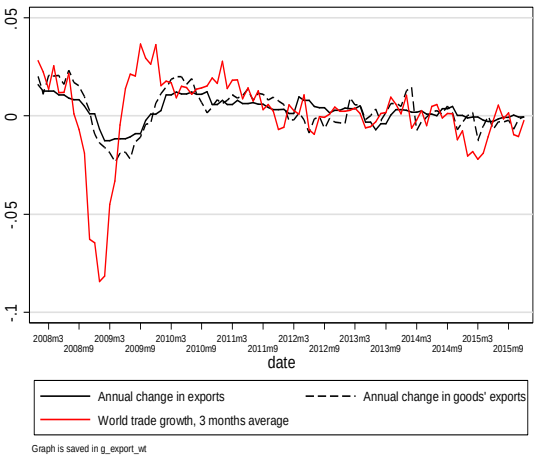
Equation	(1)	(2)	(3)	(4)	(5)	(6)
Period	2009.9-2015.12	2009.9-2011.7	2009.9-2013.3	2013.4-2015.12	2011.8-2015.12	2009.9-2011.7 & 2013.4-2015.12
No. of observations	76	23	43	33	53	56
Estimated intervention ^	0.0075*	-0.0039	0.0027	0.00	0.027**	0.0016
Δ(BoI – US federal funds rate differential)	-0.044***	-0.054***	-0.047***	-0.003	-0.024	-0.046***
Δ (dollar-currency basket exchange rate, [dxy])	-0.14*	-0.48***	-0.32***	0.43	0.062	-0.17**
Δ (Israel's 5-year CDS index)	0.08***	0.10***	0.11***	-0.17	0.01	0.05**
FDI capital inflow ^	-0.004***	-0.004**	-0.003*	-0.005	-0.005***	-0.004***
Δ (MSCI index, 3-months average)	-0.26***	0.17	-0.21**	-0.85	-0.43***	-0.13
L.(current account, 3-months average)	-1.55***	1.37	-0.87*	-6.00	-2.95***	-1.62*
Const.	0.017	-0.004	0.013**	0.020	0.022***	0.022***
R^2	0.24	0.73	0.51	-	.	0.37
RMSE	0.0113	0.007	0.0097	0.0334	0.015	0.001

^ Coefficient multiplied by 1,000. # coefficient divided by 1000. * Significant with 10%, ** 5%, *** 1%

L. = Lagged 1-month; Δ=Delta log, difference for interest rates. A positive change in the exchange rate=depreciation.

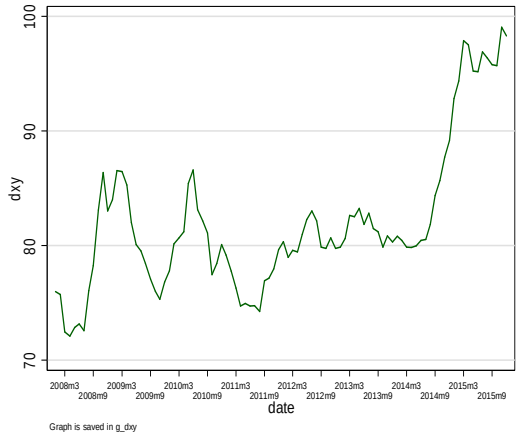
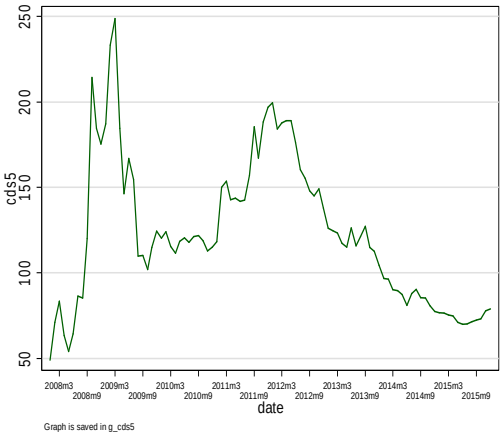
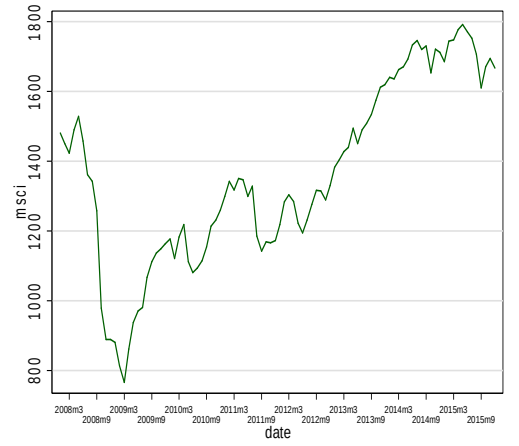
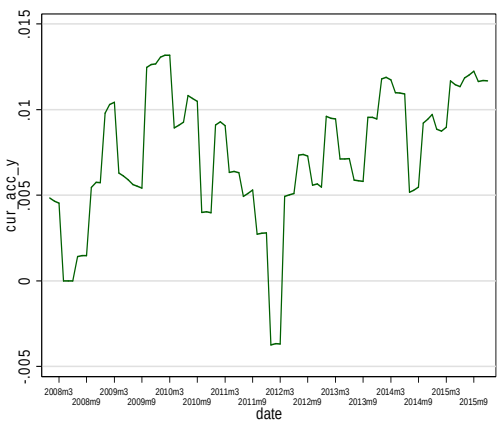
Appendix 1: The Identifying Variables in the Equation for the Intervention in the Foreign Exchange Market

The Deviation from the Equilibrium Real Exchange Rate*	Foreign Currency Reserves to GDP*
	
Capital Imports for Direct Investment—Gross and Net	**The Bank of Israel Interest Rate and the US Federal Funds Rate**
	

The Monthly Standard Deviation of the Exchange Rate	Trading Volume, Total and by Nonresidents
	
Annual CPI Inflation Rate and 1-Year Breakeven Inflation Expectations	**Total Exports and Goods Exports, Annual Change, and World Trade, 3-Months Average**
	

* See footnote 20.

Appendix 2: Explanatory Variables in the Exchange Rate Equation

DXY Exchange Rate	Israel's 5-year CDS Index
	
MSCI Index	**Ratio of Current Account Surplus to GDP**
	

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